



Guidance on Safety and Risk Management of Large Liquefied Natural Gas (LNG) Spills Over Water

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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Motivation of Sandia Guidance Report for LNG Spills over Water

- **Safety standards exist for LNG spills on land, however not for LNG spills over water**
- **Results of several previous studies differed greatly due to differences in assumptions and models used**
- **Previous studies provide little justification for accidental or intentional breach assumptions, cascading damage issues, or how an LNG spill could occur**
- **Previous studies were limited in scope with a focus on consequences, excluding modern risk management and risk mitigation considerations to improve safety and security**



Application of Guidance Information and Results

- **The information and results presented are intended to be used as guidance for conducting site-specific hazard and risk analyses**
- **The results are not intended to be used prescriptively, but rather as a guide for using performance-based approaches to analyze and responsibly manage risks to the public and property from potential LNG spills over water**

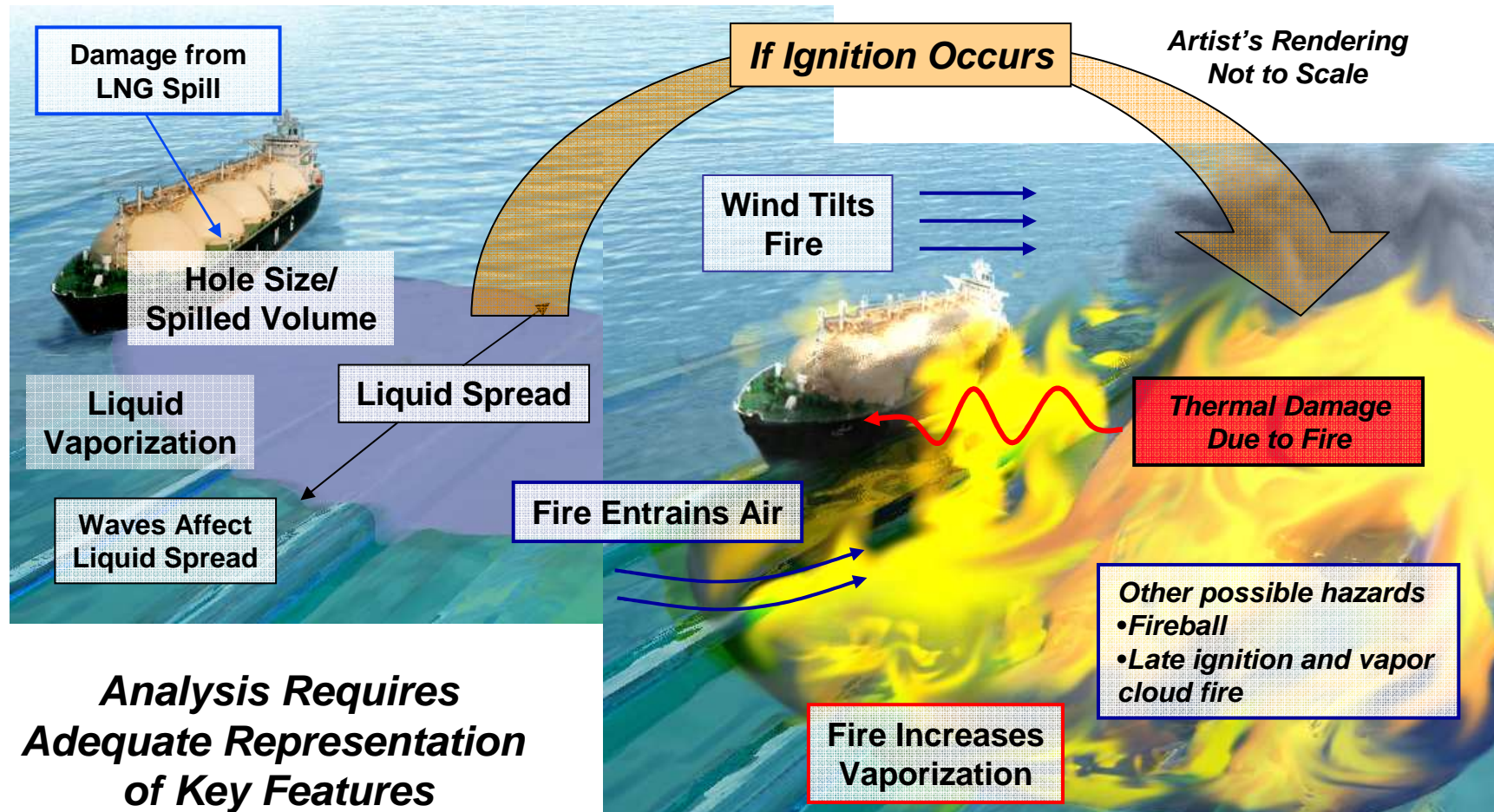


LNG Spill Safety Analysis and Risk Management Guidance

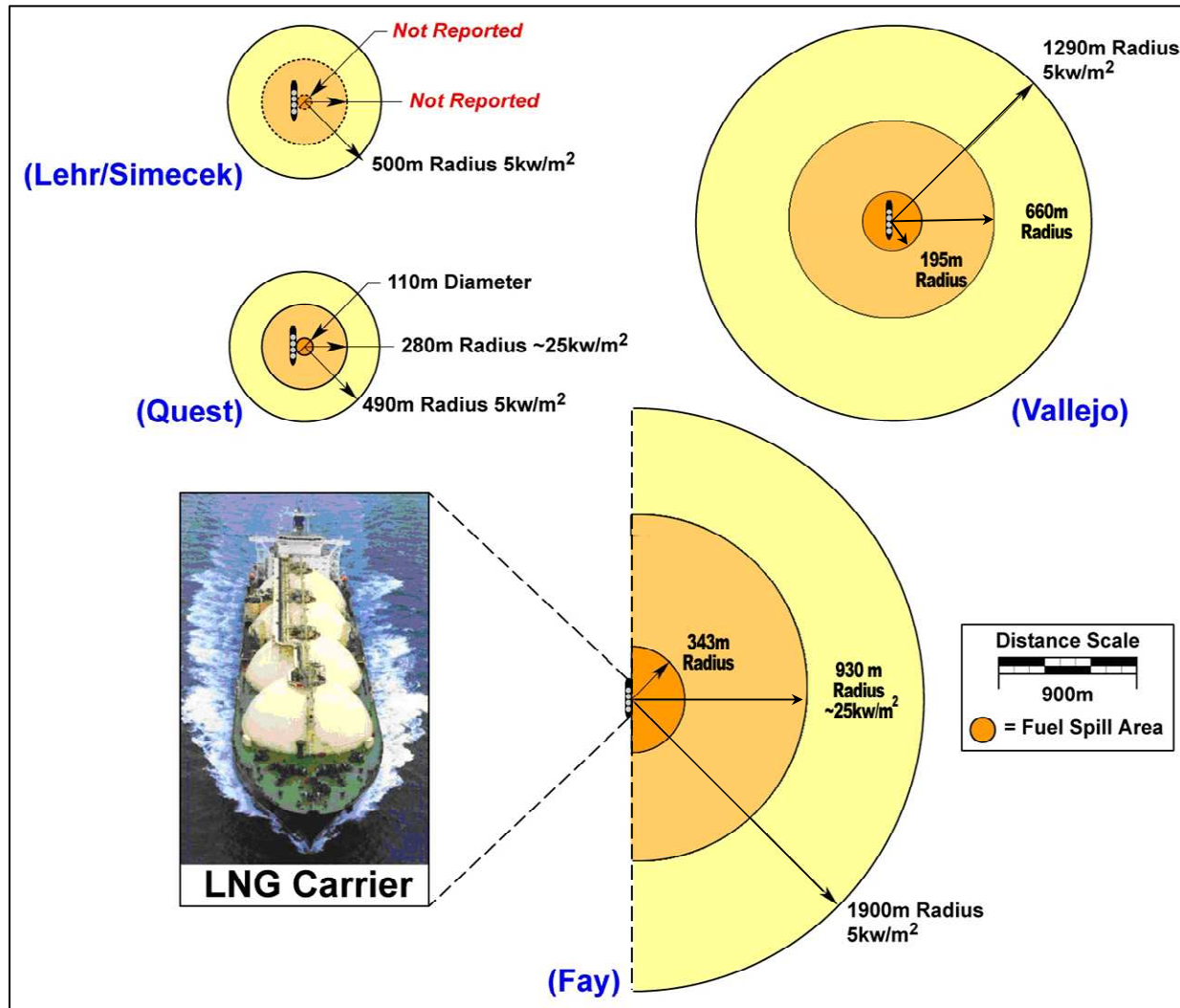
- Provides direction on hazards analyses
- Identifies “scale” of hazards from intentional events
- Provides direction on use of risk management to improve public safety
- Provides process for site-specific evaluations
- Study used many resources: experts on LNG vessel design and operations, explosion and fire modeling, intelligence and terrorism, and risk management from industry and academia



Key Features of LNG Spills Over Water



Extent of Thermal Hazards Predicted in Four Recent LNG Carrier Spill Studies



Behavior of Pool Fires

- Burn rate controls pool area and flame height
- Flame height decreases as pool diameter increases, with transition at very large diameters
- Heavier hydrocarbons produce more smoke than methane for equal diameters, smoke production unknown for LNG pool fires >35 m diameter
- Smoke shielding on average reduces the radiative heat flux level at a distance



Montoir - 35 m
LNG pool fire



SNL - 8 m
JP-8 pool fire



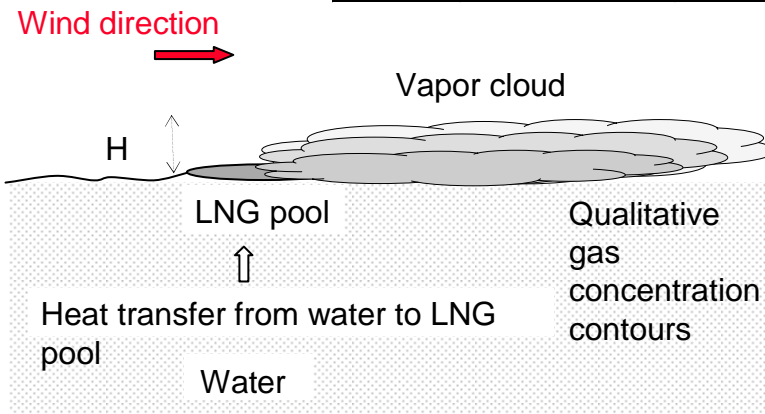
Potential Thermal Hazards for Spills from Common LNG Vessels

HOLE SIZE (m ²)	TANKS BREACH	DISCHARGE COEFF.	BURN RATE (m/s)	SURFACE EMISSIVE POWER (kW/m ²)	TRANS-MISSIV-ITY	POOL DIA. (m)	BURN TIME (min)	DISTANCE TO 37.5 kW/m ² (m)	DISTANCE TO 5 kW/m ² (m)
2	3	.6	3×10^{-4}	220	0.8	209	20	250	784
5	3	.6	3×10^{-4}	220	0.8	572	8.1	630	2118
5*	1	.6	3×10^{-4}	220	0.8	330	8.1	391	1305
5	1	.9	3×10^{-4}	220	0.8	405	5.4	478	1579
5	1	.3	3×10^{-4}	220	0.8	233	16	263	911
5	1	.6	2×10^{-4}	220	0.8	395	8.1	454	1538
5	1	.6	8×10^{-4}	220	0.8	202	8.1	253	810
5	1	.6	3×10^{-4}	220	0.5	330	8.1	297	958
5	1	.6	3×10^{-4}	175	0.8	330	8.1	314	1156
12	1	.6	3×10^{-4}	220	0.8	512	3.4	602	1920

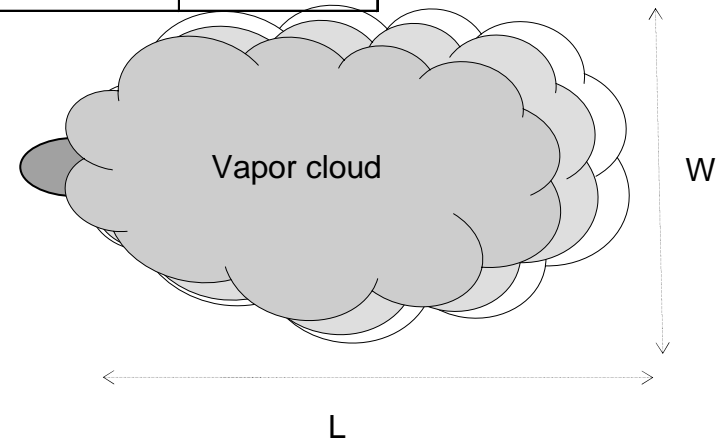
*Nominal case: Expected outcomes of a potential breach and thermal hazards based on credible threats, best available experimental data, and nominal environmental conditions for a common LNG vessel

Potential Dispersion Hazards for Spills from Common LNG Vessels

HOLE SIZE (m ²)	TANKS BREACHED	POOL DIAMETER (m)	SPILL DURATION (min)	DISTANCE TO LFL (m)
Accidental Events				
2	1	256	20	1710
Intentional Events				
5	1	405	8.1	2450
5	3	701	8.1	3614



Side View



Top View

Dispersion distances are limited by closest ignition source



Potential Thermal and Dispersion Hazards for Spills from Large LNG Vessels

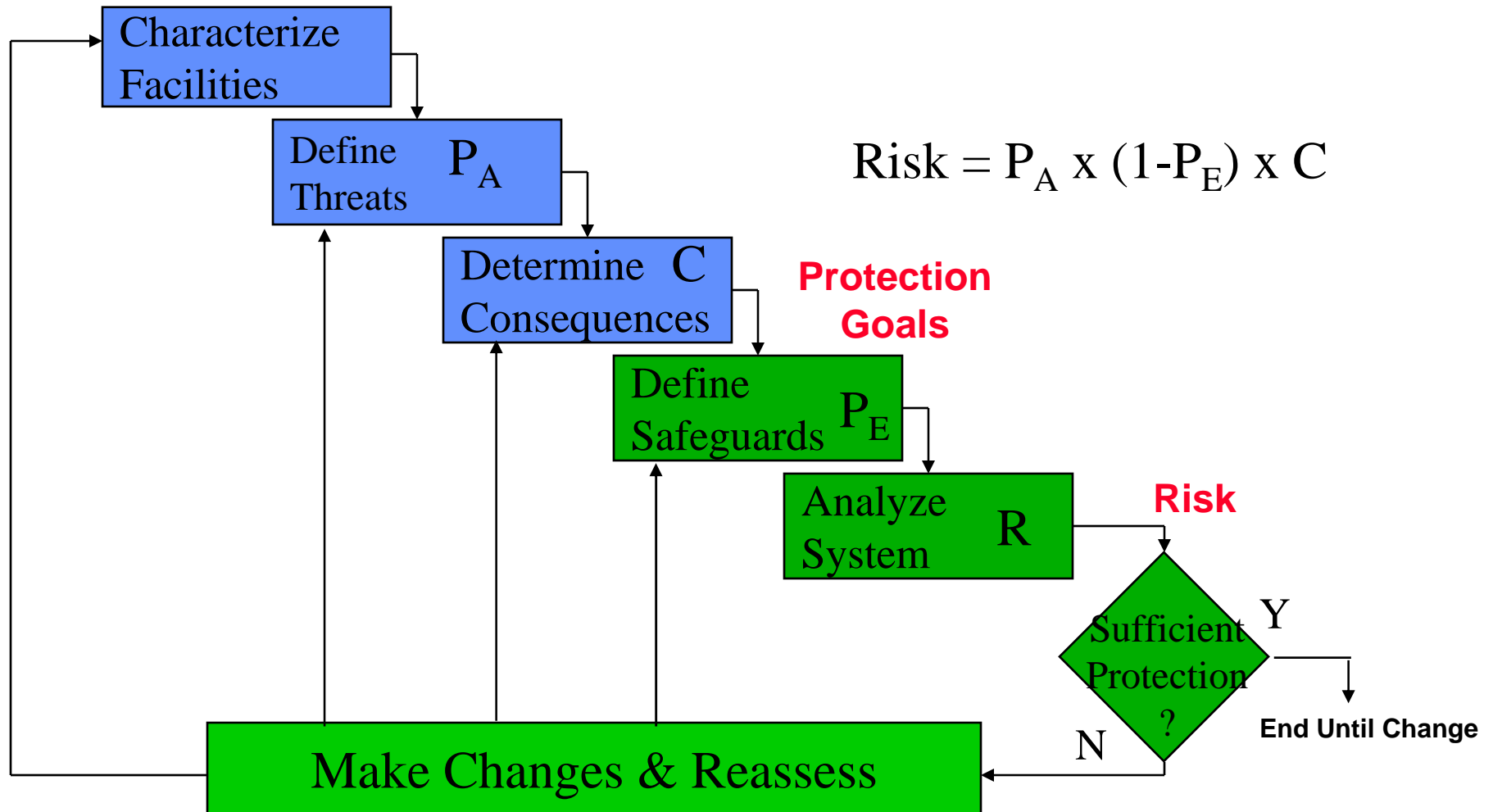
HOLE SIZE (m ²)	TANKS BREACHED	POOL DIAMETER (m)	DISTANCE TO 37.5 kW/m ² (m)	DISTANCE TO 5 kW/m ² (m)
Thermal Distances for Potential Intentional Events				
7	2	640	~750	~2500

HOLE SIZE (m ²)	TANKS BREACHED	WIND SPEED (m/sec)	DISTANCE TO LFL (m)
Dispersion Distances for Potential Intentional Events			
7	2	2	~10,000
7	2	6 (avg)	~7,000

Example hazard distances are for intentional spills of ~200,000 m³ of LNG in open areas without risk management



Performance-based Risk Assessment Approach for LNG Spills





LNG Spill Risk Management Elements

Risks can often be managed through a combination of approaches:

- **Improved risk prevention measures to reduce the likelihood of possible scenarios**
 - **Earlier ship interdiction, boardings, and searches; positive vessel control during transit; port traffic control measures; safety and security zones and surveillance; or operational changes**
- **Locating LNG terminals where risks to public safety, other infrastructures, and energy security are minimized**
- **Improved LNG transportation safety and security systems**
- **Improved hazard analysis modeling and validation**
- **Improved emergency response, evacuation, and event mitigation strategies**



Risk Management Process to Help Sites Evaluate Potential LNG Spills

Chapter 6 of Sandia report provides guidance on a process for assessing and responsibly managing risks of a LNG spill:

- **Site-specific conditions to consider**
 - location, environmental conditions, proximity to infrastructures or residential or commercial areas, ship size, and available resources
- **Site-specific threats to evaluate**
- **Cooperating with stakeholders, public safety, and public officials to identify site-specific “protection goals”**
- **Appropriate modeling and analysis approaches for a given site, conditions, and operations**
- **System safeguards and protective measures to consider**
- **Identification of approaches to manage risks, through prevention and mitigation, enhancing energy reliability and the safety of people and property**



Summary of Risk Management Guidance

- **Use of effective security and protection operations can be used to reduce the hazards and risks from a possible breaching event**
- **Risk management strategies should be based on site-specific conditions, protection goals, and the expected impact of a spill**
 - **Less intensive strategies can often be sufficient in areas where the impacts of a spill are low**
- **Where impacts to public safety and property could be high and where a spill could interact with terrain or structures – use of modern, validated Computational Fluid Dynamics models can improve hazard analyses**